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ABSTRACT

This lesson introduces the basics of sludge incineration and focuses on the multiple hearth furnace in accomplishing this task. Attention is given to component identification and function process control fundamentals, theory of incineration, safety, and other responsibilites of furnace operation. The material is rather technical and assumes an understanding of basic plant operation. The lesson includes an instructor's guide and student workbook. The instructor's guide contains a description of the lesson, estimated presentation time, instructional materials list, suggested sequence of presentation, reading lists, objectives, lecture outline, narrative of the slide/tape program used with the lesson, and student worksheet (with answers). The student workbook contains plant flow diagrams, objectives, glossary, test material on sludge incineration--multiple health furnace, references, and worksheet. (JN)

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SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166
SLUDGE INCINERATION
MULTIPLE HEARTH

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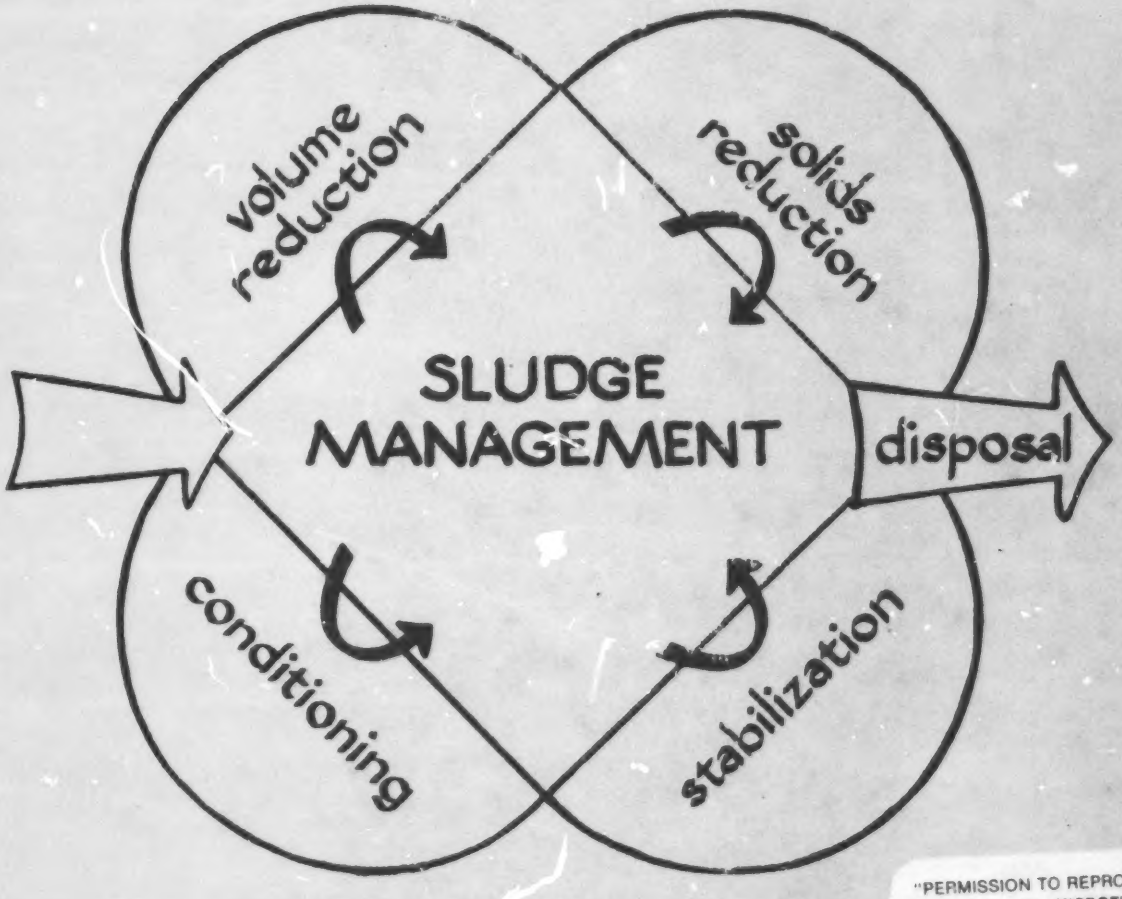

INSTRUCTOR'S GUIDE

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Linn-Benton Community College
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SLUDGE
INCINERATION
MULTIPLE HEARTH FURNACE

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SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

CONTENTS

Subject	Page
Lesson Description	MH-1
Estimated Time	MH-1
Instructional Materials List	MH-1
Suggested Sequence of Presentation	MH-1
Required Reading	MH-2
Reference Reading	MH-2
Objectives	MH-3
Lesson Outline	MH-5
Narrative	MH-14
Answers to Worksheet	W-MH-1 thru 3
Student Materials	S-MH-1 thru 17
	SW-MH-1 thru 3

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

Lesson Description

This lesson is an introduction to sludge incineration. It features the multiple hearth furnace. Since it covers the basics of sludge incineration, it is suitable for use along with a discussion of fluidized bed furnaces, the same process being accomplished with different equipment.

This material is rather technical and assumes an understanding of basic plant operation. Prior to studying this lesson, the student should be familiar with the material found in "Planning Considerations", "Sludge Characteristics", and "Sludge Conditioning". The student should also have a general level of understanding attained by completing the WPCF Basic Course.

This lesson may be presented in a slide/tape mode or an instructor may lecture from the outline while using the slide set.

Estimated Time

Student Preview of Objectives	5 - 10 minutes
Presentation of Lesson	30 - 40 minutes
Worksheet	10 - 15 minutes
Correct Worksheet and Discussion	10 - 15 minutes

Instructional Materials List

1. Student text, "Sludge Incineration - Multiple Hearth Furnace".
2. Slide/tape set, "Sludge Incineration - Multiple Hearth Furnace".
3. Slide projector, 35mm carousel.
4. Tape player with synchronization to slide projector.
5. Screen
6. Chalkboard and chalk or flip chart and marking pens.
7. Pointer
8. Samples of ash from Multiple Hearth Furnace.

Suggested Sequence of Presentation

1. Have students review the objectives and glossary.
2. Present lesson - either slide/tape or lecture format.
3. Assign worksheet.
4. Correct worksheet and discuss questions that arise.

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

Required Reading

Student text, "Sludge Incineration - Multiple Hearth Furnace".

Reference Reading

"Planning Considerations", "Sludge Characteristics", "Sludge Conditioning".

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

Objectives

Upon completion of this lesson, the student should be able to do the following:

1. Recall that combustion of sludge produces ash, CO_2 and water vapor.
2. Recall that sludge incineration reduces the volume of sludge by approximately 90%.
3. Identify the following components:
   A. Steel Cylinder
   B. Refractory Lining
   C. Center Shaft
   D. Burners
   E. Hearths
   F. Rabble Arms
   G. Rabble Teeth
4. Describe how sludge moves through a multiple hearth furnace (MHF).
5. Describe the purpose of the furnace refractory.
6. Identify the following hearth components:
   A. In-Hearth
   B. Out-Hearth
   C. Lute Cap
   D. Drop Holes
   E. Castable Insulation
7. Recall the purpose of the flap gate.
8. Define rabbling.
9. List three results of rabbling.
10. Recall the purpose of the center shaft and sand seals.
11. Recall themechanism for cooling the shaft and rabble arms.
12. Recall that the variable speed shaft drive mechanism is composed of:
    A. Bull Gear
    B. Gear Reducer
    C. Drive Motor
    D. Pinion Gear
13. Recall the purpose of the top and lower bearings.
14. Recall that the two most common types of ash handling systems are:
    A. Wet Ash System
    B. Dry Ash System

15. Arrange, in the proper sequence, the components of an off-gas system.

16. State the purpose of the following components:
    A. Cyclone
    B. Pre-cooler
    C. Venturi-scrubber
    D. Impingement Scrubber
    E. Demister
    F. Induced Draft Fan and Damper

17. List four goals of furnace operations as:
    A. Control burn
    B. Prevent damage
    C. Predict process changes
    D. Minimize costs

18. Recall the three furnace zones to be:
    A. Drying
    B. Combustion
    C. Cooling

19. State the effect of shaft speed on the location of the combustion zone.

20. State that the cause of smoke in the off-gas system is incomplete combustion.

21. List safety precautions when operating a furnace. The list should include:
    A. Protective clothing
    B. Check atmosphere before entering furance.
    C. Don't look directly into furnace.
    D. Lock-out procedure prior to entry.

22. List two examples of energy conservation measures in which excess heat is recycled to the treatment plant.

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

OUTLINE

I. INCINERATION THEORY

- A. Dewatered Cake
- B. Combustion
- C. Ash, CO_2, H_2O vapor

II. MULTIPLE HEARTH OVERVIEW

- A. Process
  1. flow direction
  2. sequence; dry, burn cool
- B. Components
  1. main cylinder
     - a. shell and lining
     - b. hearths
     - c. combustion air and burners
     - d. shaft and rabble arms
     - e. drive mechanism
  2. off-gas system
  3. ash handling

III. COMPONENTS AND FUNCTIONS

- A. Furnace
  1. Housing and Hearths
     - a. refractory lining
     - b. flap gate
     - c. hearth numbering
     - d. hearth construction
       1) in-hearths, out-hearths
       2) drop holes
  2. Central Shaft
     - a. shaft and sand seals
     - b. rabble arms and lute capseals
     - c. rabble arm cooling system
     - d. drive mechanism
  3. Burners and Combustion Air
- B. Off-Gas System
  1. Function - normal and emergency
     - a. draft in furnace
     - b. carry off combustion gases
     - c. clean pollutants

2. Components
   a. precooler
   b. Venturi scrubber
   c. impingement scrubber
   d. mist eliminator
   e. induced draft fan and emergency bypass system
   f. older systems - cyclone

C. Ash Handling

1. Definition - inorganics left over after sludge cake has burned
2. Wet Ash System - slurry to lagoons
3. Dry Ash System
   a. screw conveyer to bin
   b. wetting spray
   c. screw conveyer to truck

IV. OPERATIONS

A. 3 Zones - function, temperature ranges, operational concerns

1. Drying
2. Combustion
3. Cooling

B. Operator Goals

1. Fire in desired location
2. Protect equipment
3. Predict changes
4. Adjust to changes
5. Control of smoke -
   a. increase air
   b. slow shaft speed

V. SAFETY

A. Everything "is" hot

B. Protective clothing

C. Never look directly into furnace

VI. ENERGY DEMAND AND CONSERVATION

A. Requires energy

B. Design to recycle energy to other units in plant - heat treatment or anaerobic digestor

VII. REVIEW

A. Components

1. Main Furnace
   a. shell and hearths
   b. cake moving units - shaft and arms
2. Off Gas
3. Ash handling

B. Operation - Goals

1. Air Control
2. Burn Control
3. Smoke Control

C. Safety

D. Theory - cake to ash and gas

Narrative

Slide #

1. This lesson deals with the basics of sludge incineration and focuses on the multiple hearth furnace in accomplishing this task. Attention is given to component identification and function process control fundamentals, theory of incineration, safety and other responsibilities of furnace operation.

2. This lesson was prepared by Paul H. Klopping. Instructional design and editing was provided by Priscilla Hardin. Richard A. Best served as a writer and technical consultant.

3. Incinerators dry dewatered sludge cake and heat it to the combustion point. The resulting products are gas and ash.

4. Incineration reduces the volume and the solids in sludge cake, leaving a stable ash. Incinerator ash can be disposed of without hhe usual concern for pathogenic organisms.

5. In incineration the water and solids in dewatered cake are reduced to a small amount of ash. 90% of the original material becomes a gas that is largely CO_2 and water vapor. Disposal of the relatively inoffensive gas and ash completes the incineration process.

6. Three types of incinerators are in general use: multiple hearth furnaces, fluidized beds, and rotary kilns. This module focuses on the multiple hearth furnace.

7. A multiple hearth furnace is essentially a huge canister containing a stack of circular shelves called hearths. From the outside, observation doors and gas or oil fired burners are visible.

8. Dewatered sludge cake enters the top of the furnace and moves across each hearth, from outer edge to center or center to outer edge, on its way to the bottom. A counter current of gases and hot air rises from the lower levels causing the sludge to dry and eventually burn in the intense heat. At the bottom of the furnace, nothing remains of the sludge cake but ash.

9. Several zones develop during operation. In the upper hearths sludge cake dries and approaches the combustion point. Burning occurs primarily on one hearth about half way down the furnace. On the lower hearths, hot coals turn to dull gray or tan as the ash becomes cool enough for removal.

10. The steel cylinder which houses this process has a refractory lining of heat resistant brick.

11. Inside, the circular hearths are attached to the outer wall and slope upward toward the center of the furnace. Burners throw flame into various hearths.

12. The rotating, central shaft, like a giant tree, supports rabble arms that reach out across each hearth. As the shaft turns, rabble teeth on the arms plow the sludge back and forth until it reaches the bottom of the furnace.

13. In addition to the main furnace, two support systems complete the multiple hearth incinerator. An off-gas system cools and removes pollutants from furnace gases before releasing them to the atmosphere. An ash handling system permits removal and storage of furnace ash, prior to ultimate disposal. EAhc system is reviewed in detail, beginning with the furnace itself.

14. A closer look at the components of the furnace begins with the refractory lining of the outer shell. This heat resistant material aids combustion by conserving furnace heat. It also protects outer furnace parts and workers.

15. Inside the refractory lining, the hearths, which are labeled by number from top to bottom, are also made of non-burnable material.

16. A closer look reveals that specially designed refractory bricks fit together to make each self-supporting hearth. Similar castable material covers the central shaft and rabble arms to protect them from temperatures that may reach 1,700° Farenheit.

17. Sludge moves across in-hearths to holes, located around the center shaft, called drop holes. Through the central drop holes, sludge falls to out-hearths where it moves outward to drop holes around the rim.

18. The hearths fit as snuggly as possible around the center shaft. To prevent falling sludge and ash from entering the crack between the rotating shaft and the out-hearths, overhanging lute cap seals circle the center shaft above the drop holes.

19. Sludge travels down through the drop holes as out hearth flow and in hearth flow by turns. At the same time, a countercurrent of off-gas flow rises. At the drop holes, where these currents mingle, drying, burning or cooling are intensified.

20. Sludge enters the furnace through a flap gate at the top. The flap gate is center balanced. When cake is fed sporadically, it swings shut to conserve heat and prevent the escape of gases.

21. The rabble arms, which move sludge throughout the furnace, are driven and cooled by the central shaft.

22. Spiral ridges are left in the sludge as the rabble arms move the cake across the hearths, exposing new surfaces for drying and breaking up particles.

23. As we have seen, the center shaft supports and moves the rabble arms and teeth. It also delivers cooling air to them, prolonging their usefulness. Sand seals at the top and bottom of the shaft are important components.

24. The sand seals conserve heat and gas at the points where the turning shaft passes through the furnace shell. They also allow for expansion and contraction between shell and shaft.

25. Each seal is basically a container or reservoir of sand, surrounding the shaft. The upper sand container is attached to the furnace shell while the lower one is fastened to the shaft. In each sand reservoir the seal is created by a metal sleeve or lip that rides down in the sand constantly adjusts to the turning parts, preventing air and gases from passing through.

26. At the bottom of the furnace is a cooling air fan which forces air up through the shaft and rabble arms. A system of ducts inside the shaft and in each rabble arm circulates cooling air upward to the exhaust. In many furnaces, this preheated air returns to the middle hearths to aid combustion.

27. The shaft drive which turns this massive, rabbling system is a vital part of furnace operation. Located beneath the main cylinder, the shaft drive combines a motor and gear system.

28. The motor, usually an electrical variable speed drive, has an independent gear reducer.

29. A pinion gear transfers the power to a bull gear on the center hsaft just above the intake of the cooling air fan.

30. The entire shaft rides on a lower bearing that usually has adjustment features to balance the system. An upper bearing, at the top of the furnace, controls for wabble or lateral motion of the upper shaft.

31. The burners introduce heat to the furance which not only ignites the sludge but preheats combustion air rising from the lower hearths and heats drying air in the upper hearths.

32. Combustion air is introduced as needed through fresh air ports, cooling air returns ducts, and through furnace doors. Temperatures within the furnace are controlled by adjusting combustion air and burners.

33. In review, the main furnace components are the shell and hearth construction, the center shaft components and the burners and combustion air intakes.

34. The off gas system induces a draft through the furnace, carries off gasses from combustion and cleans them of pollutants.

35. Remember that about 90% of the sludge cake entering the furnace is converted to gas and water vapor. The off gas system must remove particles and pollutants from the gas before its release into the atmosphere.

36. A variety of equipment may combine to process off-gas but newer installations usually remove particles in two stages. A Venturi scrubber removes larger polluting particles. Finer material is then trapped by an impingement scrubber. Off-gas passes through this 2 stage system as follows.

37. First, pre-cooling sprays wet the gas and particles of ash that have just left the furnace. This protects the rest of the system from heat.

38. Next, the variable throat, Venturi scrubber recieves the off-gas. More spray hits the gas as it rushes through the narrow throat at an accelerated pace and pressure. During reexpansion, droplets of water form which contain much of the ash debris. The sharp bend in the ductwork that follows, catches the heavy droplets against its far wall and carries them off to a drain.

39. The remaining gas passes on to the impingement scrubber. After more spraying it is drawn through a series of large, perforated trays that are flooded with water. The powerful draft pulls the gas through the holes in the trays. In the bubbling water, most of the fine particles are trapped. The water flows downward, from tray to tray, picking up more particles all the time. Finally it runs to a drain and joins the Venturi scrubber water as a side stream back to the plant.

40. Before the impingment scrubber can release the clean gases to the atmosphere, it must remove the moisture from the scrubbing operation. The mist eliminator directs the gas against the side of the scrubber where droplets collect by centrifugal action. This water drains back down onto the impingement plates or trays while the cool, clean gas is drawn out the top of the scrubber.

41. Two important components complete the design of any off-gas system. First, an emergency by-pass stack stands by to release gas directly should the scrubber system break down. Second, an induced draft fan and damper provide the powerful suction required to control the movement of gases through the entire off-gas system and the furnace as well.

42. To summarize, the basic componenets of a typical off gas system include a pre-cooler spray to prepare off gas for treatment, a Venturi scrubber to remove larger particles, and a impingement scrubber to finish particle removal. The impingement scrubber has a drain to return dirty water to the plant and a mist eliminator to remove much of the moisture from the off gases. Completing the entire system is an induced draft fan and damper to control the draft throughout the furnace and off-gas system.

43. Some off gas systems include a cyclone as a primary off gas treatment. Current air quality standards require additional treatment of gases before discharge to the atmosphere.

44. Therefore, cyclone cleaners must precede additional off gas treatments such as Venturi and impingement scrubbers.

45. Cyclone cleaners receive hot, dry gases and flying particles directly from the furnace. The cyclone design sets up a spiral draft of gases which throws the flying ash and heavier particles against the walls. The particles slip down the outer walls into a bin. This ash generally goes to a haul vehicle although in some installations, as shown here, it is augered back to a hearth in the burn zone.

46. The third major system of a multiple hearth furnace installation is the ash handling system.

47. Ash is the inorganic material left after sludge cake has burned. Smooth furnace operation requires some method of ash handling, storage and disposal.

48. Two of the most common methods of ash disposal are the wet and dry ash systems. Other types of ash systems include pneumatic ash transport, ash classification and ash eductors.

49. The wet ash lagoon is the simplest of all ash handling systems. ash drops out of the furance into the mix tank where effluent water is continuously added. This ash "slurry" is pumped to a lagoon. The ash settles in the lagoon and the water is removed by evaporation or mechanical means. The ash is left to dry and eventually removed from the lagoon for disposal.

50. In a dry ash system, ash drops from the furnace into a screw conveyor and then to a bucket elevator. The bucket elevator transports the ash to a storage bin where it awaits disposal. At the bottom of the storage bin, in the ash conditioner, a screw conveyor, equipped with a series of water sprays, wets the ash so it does not create dust or blow off the truck during transport.

51. Operation of a multiple hearth furnace requires management of all the furnace components described this far. The three zones of operation may be influenced by sludge composition and loadings. Extremely wet cake or heavy feed rates may drive the combustion zone lower in the furnace as a larger drying area is required. Dry sludge, greasy sludge or light loadings may cause burning to occur higher in the furnace.

52. In the drying zone, rabbling action stirs the sludge in temperatures ranging around 200 to 800° F. The resulting evaporation brings the sludge to the combustion point.

53. In the combustion zone, the dry cake ignites around 1,300° to 1,700° F. Volatile materials are burned, releasing gases and leaving hot coals that must be cooled.

54. If combustion is incomplete, partially burned organics will be readily visible in the stack gases coming from the off gas system. Complete combustion yields a thin white or colorless smoke.

55. Remaining ash continues on its path through the cooling zone, dropping in temperature from 1,000 to 600° F. or less. Fresh combustion air moves upward, cooling the ash and becoming preheated before entering the burning zone.

56. There are 4 major goals in the successful operation of a multiple hearth furnace. The first goal is to control the burn, keeping the fire in the desired location. The second goal is to prevent damage to the equipment by careful monitoring of all systems. Third, predict process changes. Instrument readings of fire and feed permit adjustments to maintain a steady, efficient burn. The fourth goal is to minimize costs. Eenergy consumption and other costs must be kept to a minimum.

57. Safety in operations is a major concern. Above all, assume that everything is hot. When in the furnace area, wear protective clothing: hard hat, face shield, long sleeves, heavy leather gloves and long pants. Never look directly into a furnace door when the furnace is in operation. Always approach the door from the side and look in at an angle.

58. Since a furnace, when out of operation, is a confined sapce, check for toxic gases, explosive conditions, and the presence of adequate oxygen before entering.

59. Always check the temperature of the ash bed before entry. Though the furnace may be cold, the ash bed may still be several hundred degrees under the surface. Always lock out the main fuel control valve and the control power prior to furnace entry. Check and verify the operation of all safety controls and interlocks on a regular basis.

60. In addition to safety, energy conservation is another ongoing concern in multiple hearth operation. Furnaces consume costly gas or oil while burning sludge cake. One way to conserve energy is through efficient furnace operation.

61. Another form of energy conservation involves recycling heat energy from the furnace. Off gas heats boilers that support other process units in some wastewater plants.

62. Plant design may recycle off gas heat to anaerobic digesters or heat treatment units. Other uses are possible and will appear as energy conservation awareness increases.

63. We have discussed systems, operations, safety, and energy for multiple hearth furnace.

64. In summary, sludge incineration reduces the volume of wastewater solids by approximately 90%. The end products are an inert ash and gas. After being purified by an off-gas system, the gas is discharged to the atmosphere.

65. Sludge incineration produces stable end products with a significant reduction in solids mass and volume.

66. In spite of its high energy requirements, multiple hearth incineration is an alternative for solids handling which must be considered where land disposal and other methods are not feasible.

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

WORKSHEET

1. Sludge incineration is a method of converting dewatered sludge cake to two end products. What are they?

   ____ a. Dewatered sludge
   _X_ b. Ash
   ____ c. Purified water
   ____ d. Fertilizer
   _X_ e. Gas

2. Incineration reduces sludge volume by approximately how much?

   ____ a. 20%
   ____ b. 50%
   ____ c. 70%
   _X_ d. 90%
   ____ e. 100%

3. How is sludge moved through a multiple hearth furnace?

   ____ a. Air pressure
   ____ b. Vacuum
   ____ c. Auger
   _X_ d. Rabbling
   ____ e. Sludge Pump

4. What is the purpose of the furnace refractory?

   ____ a. Moves sludge through furnace.
   _X_ b. Insulation
   ____ c. Moves rabble arms.
   ____ d. Vents the off-gas.
   ____ e. Prevents formation of H_2S

5. There are two types of hearths within a multiple hearth furnace. The hearth in which the cake drops to the next lower hearth from the center is called:

   ____ a. an out-hearth
   _X_ b. an in-hearth
   ____ c. a center-hearth
   ____ d. none of the above

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE
WORKSHEET

6. What is the purpose of the flap gate in the top of the furnace?

_____ a. Lets sludge into the furnace.
_____ b. Keeps out grit and grease.
_____ c. Prevents loss of heat.
_____ d. A & B are correct.
__X__ e. A & C are correct.

7. Choose three effects produced by the process of rabbling.

_____ a. Keeps sludge cool.
__X__ b. Breaks up sludge into smaller particles.
__X__ c. Moves sludge through furnace.
_____ d. Regulates temperature in furnace.
__X__ e. Exposes more surface area of sludge to promote drying.

8. What is the purpose of the sand seals where the center shaft meets? (Choose three)

_____ a. Prevents escape of sludge.
__X__ b. Prevents escape of heat and gas.
__X__ c. Prevents entrance of air.
_____ d. Supports the weight of the center shaft.
__X__ e. Allows for expansion and contraction of the furnace shell.

9. How are the center shaft and rabble arms cooled?

_____ a. By opening air vents at each hearth.
_____ b. By the draft of the off-gas system.
_____ c. By evaporation occuring as sludge dries in the furnace.
__X__ d. By a cooling air fan located at the bottom of the furnace.
_____ e. They don't need to be cooled; they are made of resistant material.

10. Matching. Choose an answer which best describes the function of these off-gas system components:

__B__ a. Pre-cooler
__A__ b. Venturi Scrubber
__E__ c. Impingement Scrubber
__D__ d. Mist Eliminator
__C__ e. Induced Draft Fan and Damper

1. Removes particulate matter through an adjustable narrow throat.
2. Lowers temperature of exhaust gas to a point where it prevents damage to scrubbers.
3. Provides the suction which pulls gas through the off-gas system.
4. Removes water vapor from gas.
5. Flat, stainless steel plates which trap particles in a water curtain.

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE
WORKSHEET

11. Select the three zones of activity in a multiple hearth furnace.

_____ a. Thickening
__X__ b. Cooling
__X__ c. Combustion
_____ d. Conditioning
__X__ e. Drying

12. How does increasing shaft speed affect the burning zone in a MHF.

_____ a. Moves lower in furnace.
__X__ b. Moves higher in furnace.
_____ c. Stays the same.
_____ d. Causes incomplete combustion.
_____ e. None of the above.

13. What causes dirty smoke in the off-gas system

_____ a. Burning zone too high in furnace.
_____ b. Burning zone too low in furnace.
_____ c. Faulty cyclone or venturi.
__X__ d. Incomplete combustion.
_____ e. None of the above.

14. Select three safety practices in the operation of a MHF.

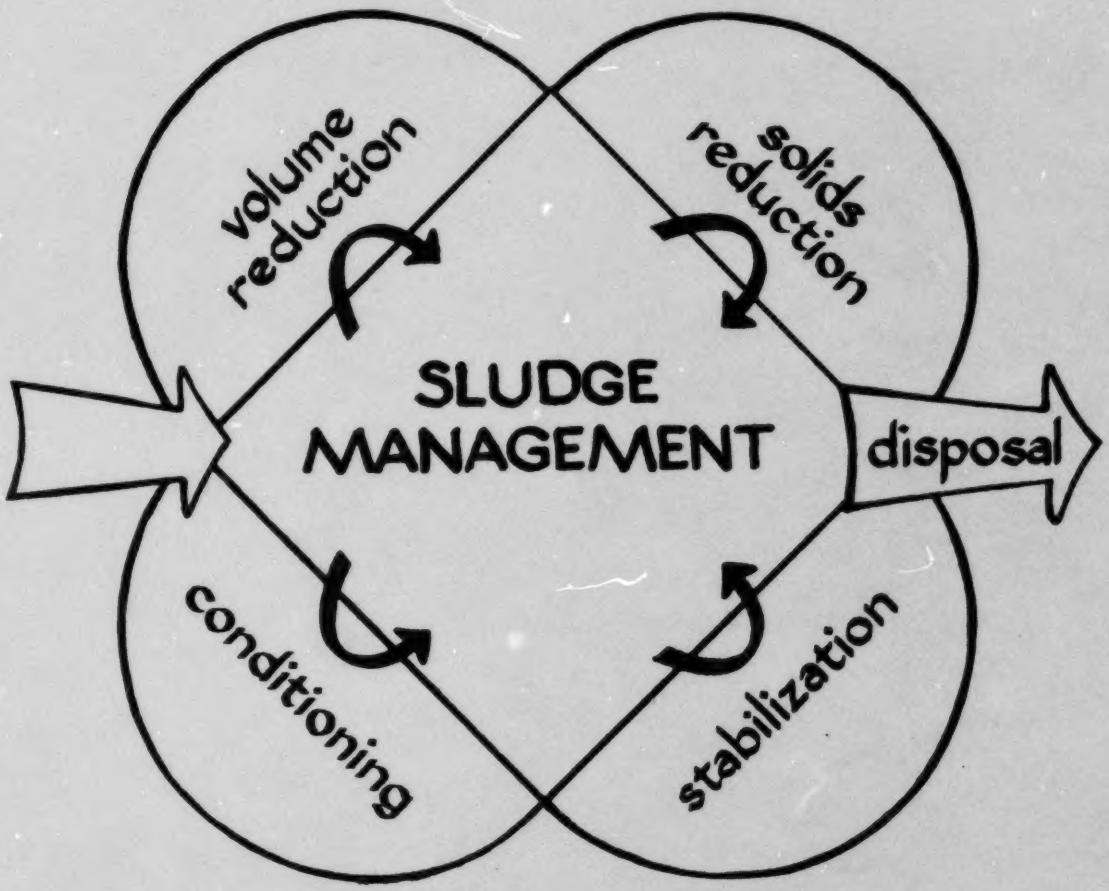
__X__ a. Wear protective clothing.
_____ b. Open the door and look directly into a hearth.
_____ c. Enter a furnace if attached by a safety harness.
__X__ d. Tag and lock out power and fuel when working in a furnace.
__X__ e. Check ash bed temperature before entry.

SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166
SLUDGE INCINERATION
MULTIPLE HEARTH FURNACE



STUDENT WORKBOOK

SE041603

Prepared by
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SLUDGE
INCINERATION
MULTIPLE HEARTH FURNACE

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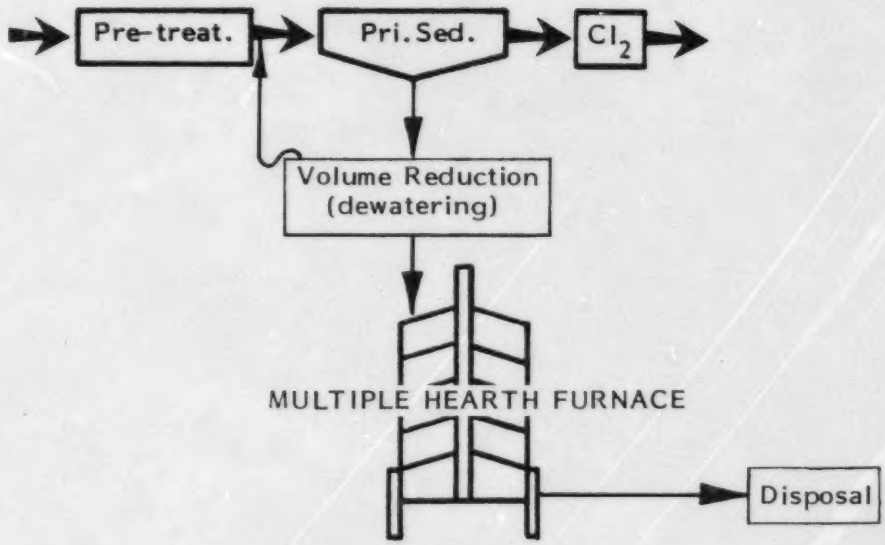
SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

CONTENTS

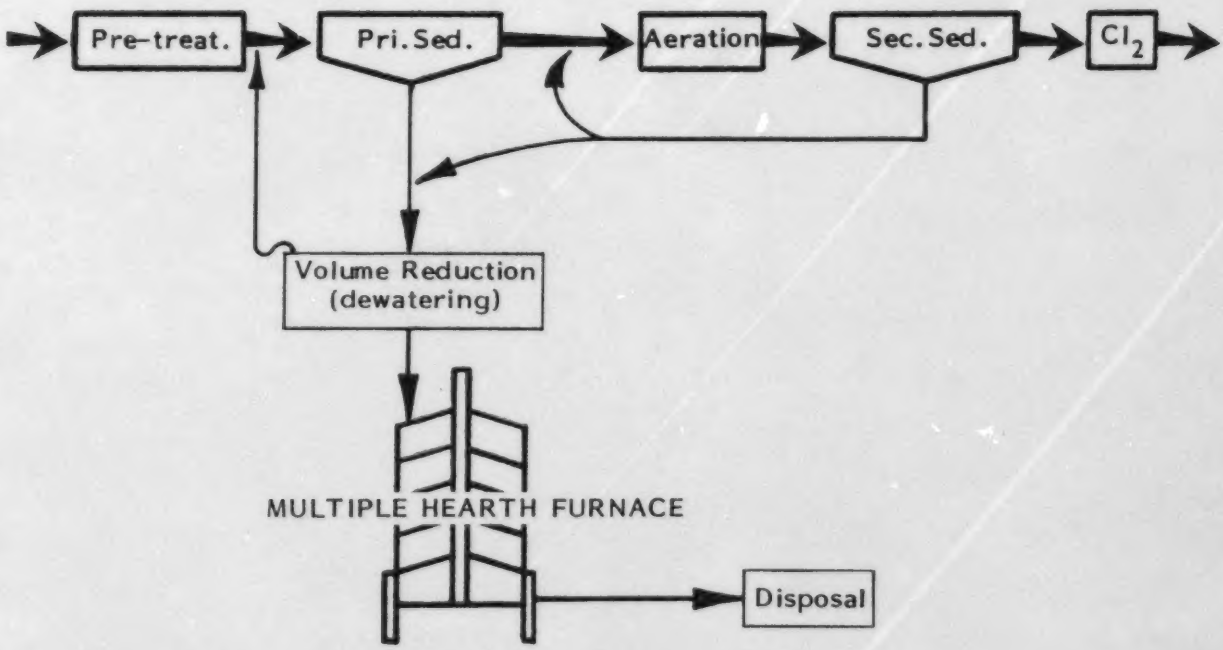
Subject	Page
Plant Flow Diagrams	S-MH-1
Objectives	S-MH-2
Glossary	S-MH-4
Sludge Incineration - MHF	S-MH-5
References	S-MH-17
Worksheet	SW-MH-1

PLANT FLOW DIAGRAMS

PRIMARY PLANT



SECONDARY PLANT



SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

Objectives

Upon completion of this lesson, the student should be able to do the following:

1. Recall that combustion of sludge produces ash, CO_2 and water vapor.
2. Recall that sludge incineration reduces the volume of sludge by approximately 90%.
3. Identify the following components:
   A. Steel Cylinder
   B. Refractory Lining
   C. Center Shaft
   D. Burners
   E. Hearths
   F. Rabble Arms
   G. Rabble Teeth
4. Describe how sludge moves through a multiple hearth furnace (MHF).
5. Describe the purpose of the furnace refractory.
6. Identify the following hearth components:
   A. In-Hearth
   B. Out-Hearth
   C. Lute Cap
   D. Drop Holes
   E. Castable Insulation
7. Recall the purpose of the flap gate.
8. Define rabbling.
9. List three results of rabbling.
10. Recall the purpose of the center shaft and sand seals.
11. Recall the mechanism for cooling the shaft and rabble arms.
12. Recall that the variable speed shaft drive mechanism is composed of:
    A. Bull Gear
    B. Gear Reducer
    C. Drive Motor
    D. Pinion Gear
13. Recall the purpose of the top and lower bearings.
14. Recall that the two most common types of ash handling systems are:
    A. Wet Ash System
    B. Dry Ash System
15. Arrange, in the proper sequence, the components of an off-gas system.

16. State the purpose of the following components:

    A. Cyclone
    B. Pre-cooler
    C. Venturi scrubber
    D. Impingement scrubber
    E. Demister
    F. Induced Draft Fan and Damper

17. List four goals of furnace operations as:

    A. Control burn
    B. Prevent damage
    C. Predict process changes
    D. Minimize costs

18. Recall the three furnace zones to be:

    A. Drying
    B. Combustion
    C. Cooling

19. State the effect of shaft speed on the location of the combustion zone.

20. State that the cause of smoke in the off-gas system is incomplete combustion.

21. List safety precautions when operating a furnace. The list should include:

    A. Protective clothing
    B. Check atmosphere before entering furnace.
    C. Don't look directly into furnace.
    D. Lock-out procedure prior to entry.

22. List two examples of energy conservation measures in which excess heat is recycled to the treatment plant.

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

GLOSSARY

Counter-Current - A situation where two flows pass each other from an opposite direction, i.e., one goes up, the other goes down.

Drop Holes - Holes in the floor of a hearth which permit sludge to drop to the next lower hearth.

Hearth - A brick floor resistant to high temperature.

Inert - Deficient in active properties; esp: lacking a usual or anticipated chemical or biological action.

In-Hearth - A type of hearth in a multiple hearth furnace which allows sludge to drop to the next lower hearth from the inside, around the center shaft of the furnace.

Off-Gas - Gas which leaves a processing unit.

Out-Hearth - A type of hearth in a multiple hearth furnace which has holes around the outside. This allows sludge to drop to the next lower hearth around the periphery of the furnace.

Rabbling - Moving or plowing sludge in a MHF due to the rotation of rabble arms and teeth.

Refractory - Brick resistant to high temperature.

Slurry - A mixture of solids and water.

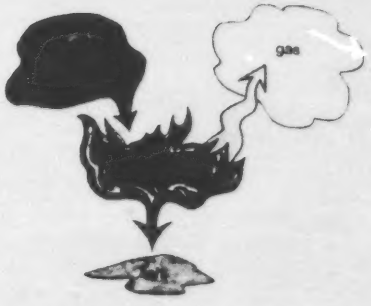
MULTIPLE HEARTH FURNACE

This lesson was prepared by Paul H. Klopping. Instructional design and editing was provided by Priscilla Hardin. Richard A. Best served as a writer and technical consultant.

This lesson deals with the basics of sludge incineration and focuses on the multiple hearth furnace in accomplishing this task. Attention is given to component identification and function, process control fundamentals, theory of incineration, safety and other responsibilities of furnace operation.

INCINERATION THEORY

Incinerators dry dewatered sludge cake and heat it to the combustion point. The resulting products are gas and ash.



Incineration reduces the volume and the solids in sludge cake, leaving a stable ash. Incinerator ash can be disposed of without the usual concern for pathogenic organisms.

In incineration the water and solids in dewatered cake are reduced to a small amount of ash. 90% of the original material becomes a gas that is largely CO_2 and water vapor. Disposal of the relatively inoffensive gas and ash completes the incineration process.

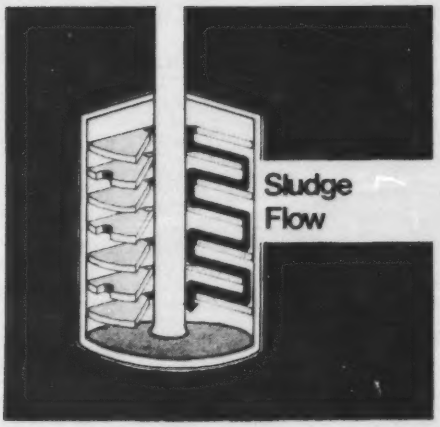
TYPES OF INCINERATORS

* multiple hearth furnace
* fluidized bed
* rotary kiln

Three types of incinerators are in general use: multiple hearth furnaces, fluidized beds, and rotary kilns. This module focuses on the multiple hearth furnace.

A multiple hearth furnace is essentially a huge canister containing a stack of circular shelves

called hearths. From the outside, observation doors and gas or oil fired burners are visible.



Dewatered sludge cake enters the top of the furnace and moves across each hearth, from outer edge to center or center to outer edge, on its way to the bottom. A counter current of hot air and gases rises from the lower levels causing the sludge to dry and eventually burn in the intense heat. At the bottom of the furnace, nothing remains of the sludge cake but ash.

FURNACE ZONES

* drying
* combustion
* cooling

Several zones develop during operation. In the upper hearths sludge cake dries and approaches the combustion point. Burning occurs primarily on one hearth about half way down the furnace. On the lower hearths, hot coals turn to dull gray or tan as the ash becomes cool enough for removal.

The steel cylinder which houses this process has a refractory lining of heat resistant brick.

Inside, the circular hearths are attached to the outer wall and slope upward toward the center of the furnace. Burners throw flame into various hearths.

The rotating, central shaft, like a giant tree, supports rabble arms that reach out across each hearth. As the shaft turns, rabble teeth on the arms plow the sludge back and forth until it reaches the bottom of the furnace.

In addition to the main furnace, two support

SYSTEMS

*furnace
*off gas
*ash handling

systems complete the multiple hearth incinerator. An off-gas system cools and removes pollutants from furnace gases before releasing them to the atmosphere. An ash handling system permits removal and storage of furnace ash, prior to ultimate disposal. Each system is reviewed in detail, beginning with the furnace itself.

FURNACE COMPONENTS & FUNCTIONS

A closer look at the components of the furnace begins with the refractory lining of the outer shell. This heat resistant material aids combustion by conserving furnace heat. It also protects outer furnace parts and workers.

Outer Shell

Hearths

Inside the refractory lining, the hearths, which are labeled by number from top to bottom, are also made of non-burnable material.

Specially designed refractory bricks fit together to make each self-supporting hearth. Similar castable material covers the central shaft and rabble arms to protect them from temperatures that may reach 1,700^{0} Farenheit.

Drop Holes

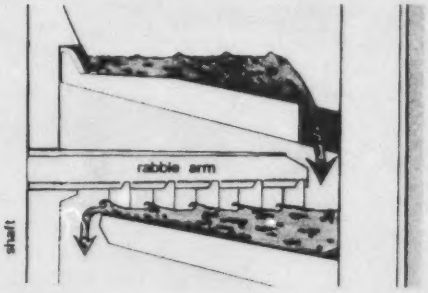
Sludge moves across in hearths to holes, located around the center shaft, called drop holes. Through the central drop holes, sludge falls to out hearths where it moves outward to drop holes around the rim.

The hearths fit as snugly as possible around the center shaft. To prevent falling sludge and ash from entering the crack between the rotating shaft and the out hearths, overhanging lute cap seals circle the center shaft above the drop holes.

Sludge travels down through the drop holes as out hearth flow and in hearth flow by turns. At the same time, a countercurrent of off gas flow rises. At the drop holes, where these currents mingle, drying, burning or cooling are intensified.

Flap Gate Sludge enters the furnace through a flap gate at the top. The flap gate is center balanced. When cake is fed sporadically, it swings shut to conserve heat and prevent the escape of gases.

Rabble Arms and Teeth



The rabble arms, which move sludge throughout the furnace, are driven and cooled by the central shaft.

Spiral ridges are left in the sludge as the rabble arms move the cake across the hearths, exposing new surfaces for drying and breaking up particles.

Center Shaft As we have seen, the center shaft supports and moves the rabble arms and teeth. It also delivers cooling air to them, prolonging their usefulness. Sand seals at the top and bottom of the shaft are important components.

The sand seals conserve heat and gas at the points where the turning shaft passes through the furnace shell. They also allow for expansion and contraction between shell and shaft.

Each seal is basically a container or reservoir of sand, surrounding the shaft.

The upper sand container is attached to the

furnace shell while the lower one is fastened to the shaft. In each sand reservoir the seal is created by a metal sleeve or lip that rides down in the sand as the shaft turns. The loose sand constantly adjusts to the turning parts, preventing air and gases from passing through.

Shaft Cooling At the bottom of the furnace is a cooling air fan which forces air up through the shaft and rabble arms. A system of ducts inside the shaft and in each rabble arm circulates cooling air upward to the exhaust. In many furnaces, this preheated air returns to the middle hearths to aid combustion.

Shaft Drive The shaft drive which turns this massive, rabbling system is a vital part of furnace operation. Located beneath the main cylinder, the shaft drive combines a motor and gear system.

The motor, usually an electrical variable speed drive, has an independent gear reducer.

A pinion gear transfers the power to a bull gear on the center shaft just above the intake of the cooling air fan.

The entire shaft rides on a lower bearing that usually has adjustment features to balance the system. An upper bearing, at the top of the furnace, controls for wobble or lateral motion of the upper shaft.

Burners The burners introduce heat to the furnace which not only ignites the sludge but preheats combustion air rising from the lower hearths and heats drying air in the upper hearths.

Combustion air is introduced as needed through fresh air ports, cooling air return ducts, and through furnace doors. Temperatures within the furnace are controlled by adjusting combustion air and burners.

In review, the main furnace components are the shell and hearth construction, the center shaft components and the burners and combustion air intakes.

OFF GAS SYSTEM The off gas system induces a draft through the furnace, carries off gasses from combustion and cleans them of pollutants.

Remember that about 90% of the sludge cake entering the furnace is converted to gas and water vapor. The off gas system must remove particles and pollutants from the gas before its release into the atmosphere.

A variety of equipment may combine to process off gas but newer installations usually remove particles in two stages. A Venturi scrubber removes larger, polluting particles. Finer material is then trapped by an impingement scrubber. Off gas passes through this two stage system as follows:

Pre-cooler First, pre-cooling sprays wet the gas and particles of ash that have just left the furnace. This protects the rest of the system from heat.

Venturi Scrubber Next, the variable throat, Venturi scrubber recieves the off gas. More spray hits the gas as it rushes through the narrow throat at an ac-

celerated pace and pressure. During reexpansion, droplets of water form which contain much of the ash debris. The sharp bend in the ductwork that follows catches the heavy droplets against its far wall and carries them off to a drain.

Impingement Scrubber

The remaining gas passes on to the impingement scrubber. After more spraying it is drawn through a series of large, perforated trays that are flooded with water. The powerful draft pulls the gas through the holes in the trays. In the bubbling water, most fine particles are trapped. The water flows downward, from tray to tray, picking up more particles all the time. Finally it runs to a drain and joins the Venturi scrubber water as a side stream back to the plant.

Mist Eliminator or Demister

Before the impingement scrubber can release the clean gases to the atmosphere, it must remove the moisture from the scrubbing operation. The mist eliminator directs the gas against the side of the scrubber where droplets collect by centrifugal action. This water drains back down onto the impingement plates or trays while the cool, clean gas is drawn out the top of the scrubber.

Emergency By-pass

Induced Draft Fan

Two important components complete the design of any off gas system. First, an emergency by-pass stack stands by to release gas directly should the scrubber system break down. Second, an induced draft fan and damper provide the powerful suction required to control the movement of gases through the entire off gas system and the furnace as well.

To summarize, the basic components of a typical off gas system include a pre-cooler spray to prepare off gas for treatment, a Venturi scrubber to remove many particles, and an impingement scrubber to finish particle removal. The impingement scrubber has a drain to return dirty water to the plant and a mist eliminator to remove much of the moisture from the off gases. Completing the entire system is an induced draft fan and damper to control the draft throughout the furnace and off gas system.

Cyclone Option

Some off gas systems include a cyclone as a primary off gas treatment. Current air quality standards require additional treatment of gases before discharge to the atmosphere.

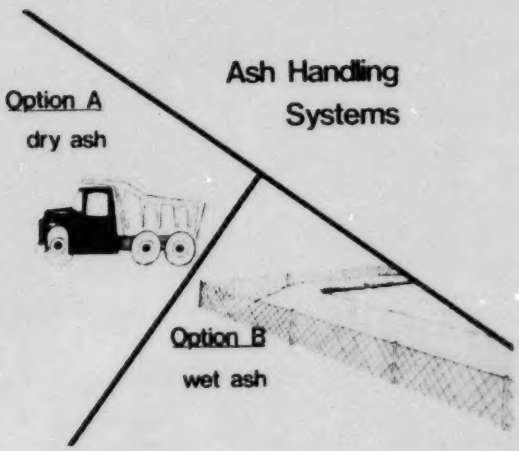
Therefore, cyclone cleaners must precede additional off gas treatments such as Venturi scrubbers and impingement scrubbers.

Cyclone cleaners receive hot, dry gases and flying particles directly from the furnace. The cyclone design sets up a spiral draft of gases which throws the flying ash and heavier particles against the walls. The particles slip down the outer walls into a bin. This ash generally goes to a haul vehicle although in some installations, it is augered back to a hearth in the burn zone.

ASH HANDLING SYSTEM

The third major system of a multiple hearth furnace installation is the ash handling system.

Ash is the inorganic material left after sludge cake has burned. Smooth furnace operation requires some method of ash handling, storage and



disposal.

Two of the most common methods of ash disposal are the wet and dry ash systems. Other types of ash systems include pneumatic ash transport, ash classification and ash eductors.

The wet ash lagoon is the simplest of all ash handling systems. The ash drops out of the furnace into a mix tank where effluent water is continuously added. This ash "slurry" is pumped to a lagoon. The ash settles in the lagoon and the water is removed by evaporation or mechanical means. The ash is left to dry and eventually removed from the lagoon for disposal.

In a dry ash system, ash drops from the furnace into a screw conveyor and then to a bucket elevator. The bucket elevator transports the ash to a storage bin where it awaits disposal. At the bottom of the storage bin, in the ash conditioner, a screw conveyor, equipped with a series of water sprays, wets the ash so it does not create dust or blow off the truck during transport.

OPERATIONS

Operation of a multiple hearth furnace requires management of all the furnace components described this far. The three zones of operation may be influenced by sludge composition and loadings. Extremely wet cake or heavy feed rates may drive the combustion zone lower in the furnace as a larger drying area is required. Dry sludge, greasy sludge or light loadings may cause burning to occur higher in

the furnace.

Zone Functions and Temperatures

* Drying, 200°-800°F
* Combustion, 1,300°-1,700°F
* Cooling, 1,000°-600°F

In the drying zone, rabbling action stirs the sludge in temperatures ranging from 200° to 800° F. The resulting evaporation brings the sludge to the combustion point.

In the combustion zone, the dry cake ignites around 1,300° to 1,700° F. Volatile materials are burned, releasing gases and leaving hot coals that must be cooled.

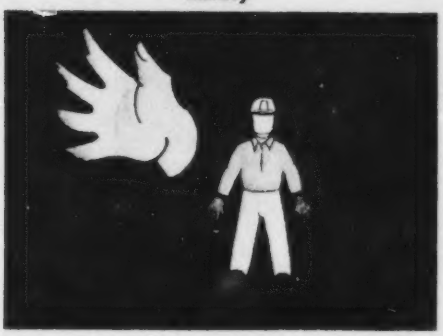
If combustion is incomplete, partially burned organics will be readily visible in the stack gases coming from the off gas system. Complete combustion yields a thin white or colorless smoke.

Remaining ash continues on its path through the cooling zone, dropping in temperature from 1,000° F to 600° F or less. Fresh combustion air moves upward, cooling the ash and becoming preheated before entering the burning zone.

There are 4 major goals in the successful operation of a multiple hearth furnace. The first goal is to control the burn, keeping the fire in the desired location. The second goal is to prevent damage to the equipment by careful monitoring of all systems. Third, predict process changes. Instrument readings of fire and feed permit adjustments to maintain a steady, efficient burn. The fourth goal is to minimize costs. Energy consumption and other costs must be kept to a minimum.

SAFETY Safety in operation is a major concern. Above all, assume that everything is hot! When in the furnace area, wear protective clothing: hard hat, face shield, long sleeves, heavy leather gloves and long pants. Never look directly into a furnace door when the furnace is in operation. Always approach the door from the side and look in at an angle.

Safety



Since a furnace, when out of operation, is a confined space, check for toxic gases, explosive conditions, and the presence of adequate oxygen before entering.

Always check the temperature of the ash bed before entry. Though the furnace may be cold, the ash bed may still be several hundred degrees under the surface. Always lock out the main fuel control valve and the control power prior to furnace entry. Check and verify the operation of all safety controls and interlocks on a regular basis.

ENERGY CONSERVATION In addition to safety, energy conservation is another ongoing concern in multiple hearth operation. Furnaces consume costly gas or oil while burning sludge cake. One way to conserve energy is through efficient furnace operation.

Recycled Heat Uses Another form of energy conservation involves recycling heat energy from the furnace. Off gas heats boilers that support other process units in some wastewater plants.

Plant design may recycle off gas heat to anaerobic digesters or heat treatment units. Other uses are possible and will appear as

energy conservation awareness increases.

CONCLUSION In summary, sludge incineration reduces the volume of wastewater solids by approximately 90%. The end products are an inert ash and gas. After being purified by an off-gas system, the gas is discharged to the atmosphere.

Sludge incineration produces stable end products with a significant volume and solids reduction.

In spite of its high energy requirements, it is an alternative for solids handling which must be considered where land disposal and other methods are not feasible.

References

1. Process Design Manual for Sludge Treatment and Disposal, USEPA, EPA 625/1-79-011, Cincinnati, 1979.

2. Operations Manual, Sludge Handling and Conditioning, USEPA, EPA 430/9-78-002, Washington, D.C., 1978.

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE
WORKSHEET

6. What is the purpose of the flap gate in the top of the furnace?

_____ a. Lets sludge into the furnace.

_____ b. Keeps out grit and grease.

_____ c. Prevents loss of heat.

_____ d. A & B are correct.

_____ e. A & C are correct.

7. Choose three effects produced by the process of rabbling.

_____ a. Keeps sludge cool.

_____ b. Breaks up sludge into smaller particles.

_____ c. Moves sludge through furnace.

_____ d. Regulates temperature in furnace.

_____ e. Exposes more surface area of sludge to promote drying.

8. What is the purpose of the sand seals where the center shaft meets? (Choose three)

_____ a. Prevents escape of sludge.

_____ b. Prevents escape of heat and gas.

_____ c. Prevents entrance of air.

_____ d. Supports the weight of the center shaft.

_____ e. Allows for expansion and contraction of the furnace shell.

9. How are the center shaft and rabble arms cooled?

_____ a. By opening air vents at each hearth.

_____ b. By the draft of the off-gas system.

_____ c. By evaporation occuring as sludge dries in the furnace.

_____ d. By a cooling air fan located at the bottom of the furnace.

_____ e. They don't need to be cooled; they are made of resistant material.

10. Matching. Choose an answer which best describes the function of these off-gas system components:

_____ a. Pre-cooler

_____ b. Venturi Scrubber

_____ c. Impingement Scrubber

_____ d. Mist Eliminator

_____ e. Induced Draft Fan and Damper

1. Removes particulate matter through an adjustable narrow throat.
2. Lowers temperature of exhaust gas to a point where it prevents damage to scrubbers.
3. Provides the suction which pulls gas through the off-gas system.
4. Removes water vapor from gas.
5. Flat, stainless steel plates which trap particles in a water curtain.

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE

WORKSHEET

1. Sludge incineration is a method of converting dewatered sludge cake to two end products. What are they?

   _____ a. Dewatered sludge

   _____ b. Ash

   _____ c. Purified water

   _____ d. Fertilizer

   _____ e. Gas

2. Incineration reduces sludge volume by approximately how much?

   _____ a. 20%

   _____ b. 50%

   _____ c. 70%

   _____ d. 90%

   _____ e. 100%

3. How is sludge moved through a multiple hearth furnace?

   _____ a. Air pressure

   _____ b. Vacuum

   _____ c. Auger

   _____ d. Rabbling

   _____ e. Sludge Pump

4. What is the purpose of the furnace refractory?

   _____ a. Moves sludge through furnace.

   _____ b. Insulation

   _____ c. Moves rabble arms.

   _____ d. Vents the off-gas.

   _____ e. Prevents formation of H_2S

5. There are two types of hearths within a multiple hearth furnace. The hearth in which the cake drops to the next lower hearth from the center is called:

   _____ a. an out-hearth

   _____ b. an in-hearth

   _____ c. a center-hearth

   _____ d. none of the above

SLUDGE INCINERATION - MULTIPLE HEARTH FURNACE
WORKSHEET

11. Select the three zones of activity in a multiple hearth furnace.

_____ a. Thickening
_____ b. Cooling
_____ c. Combustion
_____ d. Conditioning
_____ e. Drying

12. Recycled heat from the incinerator can be used to:

_____ a. pre-heat sludge for heat-treatment process.
_____ b. maintain temperature in anaerobic digestion.
_____ c. heat treatment facility buildings
_____ d. all of the above.
_____ e. none of the above.

13. What causes dirty smoke in the off-gas system

_____ a. Burning zone too high in furnace.
_____ b. Burning zone too low in furnace.
_____ c. Faulty cyclone or venturi.
_____ d. Incomplete combustion.
_____ e. None of the above.

14. Select three safety practices in the operation of a MHF.

_____ a. Wear protective clothing.
_____ b. Open the door and look directly into a hearth.
_____ c. Enter a furnace if attached by a safety harness.
_____ d. Tag and lock out power and fuel when working in a furnace.
_____ e. Check ash bed temperature before entry.